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Bayesian Analysis of Infant Mortality in Oyo State, Nigeria

[1]Adesina, Oluwaseun A, [2]Akinlade Yemisi. O, [3]Fantola, Jubril O, and [4]Onatunji Adewale P
[2&3]The Polytechnic, Ibadan, Oyo State, and [1 & 4]Ladoke Akintola University of Technology, Ogbomoso, Oyo state.

Abstract:- Decrease in Infant Population (IP) is a product of Prenatal and Antenatal Attention (PAA) available for women of reproductive age. This does not only become a concern to health policy makers but also to pregnant women in Oyo State. Despite many Maternity health centres (MHCs), there is no adequate PAA and appropriate model for IP measured as infant mortality that can statistically investigate the effects of PAA in Oyo State. This study is aimed to develop Bayesian Binomial logit model for infant mortality when little information available about PAA. The posterior Odds ratios obtained reveal that probability of increasing PAA increases the probability of infant survival after birth. The BBLM derived for IP is adequate and that health impacts of government health post and private clinic are not probabilistically related to infant survival before and after birth in Oyo State. Health policy makers at all levels of government should make adequate provision of health facilities and employment of medical personnels for MHCs in Oyo State in order to increase the chance of infant survival at birth.

Keywords:- *Bayesian Binomial logit model, Posterior Odds Ratio, Infant Mortality, Prenatal and Antenatal, Oyo State health Centres.*

I. INTRODUCTION

The knowledge of population changes is very important to government agencies and to planning organization in order to estimate nation and local needs in education, employment, health services, housing, social security and defence. Demographic data come from a census or survey to determine size and composition from vital registration. Therefore, this seeks to know, the level of performance in some form of behaviour in the population for the birth and death rates, the changes in the level of performance during some period of observations and the examination of patterns of variation with the population. The changes in the size and structure of population are determined by three demographic variables viz-a-viz fertility, mortality and migration. The 5th Millennium Development Goal (MGDs) of the United Nations set a goal to reduce infant and maternal mortality by three-quarters for all national and regional populations between 1990 and 2015. Gayawan (2014) analyzes spatial pattern in choice of place of delivery in Nigeria. The method of a multi-categorical response with a multinomial logistic regression were incorporated using the data set obtained from Nigerian Demographic and Health Survey (2008). It was revealed that people in the north - south prefer to give birth in hospitals than in their homes. Onatunji and Adesina (2016) reported odds and hazard ratios of infant and child mortality on using the real datasets extracted from Nigeria Demographic and Health Survey (NDHS, 2013). This study revealed that mother's level of education, place of delivery and household income significantly decrease the chance of infant and child mortality after birth. Adekanmbi *et.al*. (2016) aimed to identify predictors of variations of childhood mortality between Nigerian and high-risk communities where childhood mortality was higher than expected. Nigeria Demographic and Health Survey data in 2013 was used to employ prognostic univariable and multivariable mixed Poisson regression models. Also Likelihood ratio test, Hosmer-Lemeshow goodness-of-fit, and variance inflation factor were used to estimate the fitness of the final model. It was discovered that communities with high ratings of maternal socioeconomic and multiple childhood deprivation were significantly associated with the risk of childhood mortality and also childhood mortality risks were lower in areas with higher maternal hospital-based health seeking behaviors and more favorable environmental conditions. Adesina et.al (2022) aimed at determining the factors responsible for maternal and infant mortality and also examined the causes of infant and maternal mortality in Nigeria 2000 and 2019, the data was collected from National population commission, National Bureau of Statistics and World bank indicators for Nigeria which cover a period of 19 years. The descriptive statistics of the skewness shows that the distribution of the data is fairly symmetrical and the time plot displays a downward and gradual decreasing trend for both maternal and infant mortality over the considerable years. The trend analysis of the model produces forecast performance with percentage accuracy measures of MAPE with 3% and 2% for both maternal and infant mortality. The exploratory data analysis (EDA) of maternal and infant mortality shows that the prevalence of undernourishment rate were significant to the model at 5% level of significant. Therefore, prevalence of undernourishment rate is the major factor affecting the death of the child and mother at the child birth. Hence, the government are hereby implored to improve on training levels of pregnant women at the antenatal stages. Adetola *el.al.* (2011) studied is to ascertain the Neonatal Mortality Rate (NMR), the causes of death, and the risk factors related to hospital live births in a Nigerian suburban population. Live newborns were enrolled at birth and followed up in their homes for 28 days. Verbal communications were used to ascertain the causes of death outside the hospital and extracted the causes of death from hospital records. The result showed that the NMR was 32.1 per 1000 live births and that severe perinatal asphyxia, low birth weight, and infections were the main causes of death. Lack of antenatal care, prolonged membrane rupture, maternal neonatal fever, and prematurity were the risk factors. Iyun (2000) examined the relative significance of maternal and environmental factors on child mortality in two distinct towns in southwestern Nigeria and discovered that domestic environmental conditions were a better predictor of

child mortality within the study town of Ota than the town of Iseyin. However, maternal factors, particularly age at marriage, age at first birth, and parity were statistically significant predictors of child mortality in both locations. Additionally, the mother's education was significant in the urbanized centre which is inconsistent with child mortality.

Alaba and Godwin (2019) in their study, Bayesian hierarchical modelling was used to investigate infant mortality and its risk factors In Nigeria, the variations in infant deaths within and between groups (states and regions) were examined through the problem of the hierarchical structure by using the data obtained from the fifth round of the Multiple Indicator Survey to determine the impact of individual-level variables on the risk of a child dying before the age of one. It was revealed that South West Nigeria had the lowest risk of infant deaths, while Northern Nigeria had a higher risk of infant deaths than other regions, also factors such as urban place of residence, mothers having secondary and tertiary education, first birth and birth interval above 2 years were having the lowest risk of infant deaths while Male infants, birth interval of fewer than 2 years, mothers with primary and no education, teenage mothers and mothers that gave birth at age 35 years and above were having a higher risk of infant mortality. Egbon et. al (2022) studied the quantified survival probabilities and the impact of socioeconomic and demographic factors, proximate and biological determinants, and environmental factors on the risk of under-five mortality in Nigeria, the method of Bayesian mixed effect hierarchical hazard modelling framework with spatial components was employed using the dataset of 2018 Nigeria Demographic and Health Survey. It was reported that the probability of a child dying within the first two months is 0.04, and a boy child and a girl dying before turning age five are 0.106 and 0.094 respectively. The significant risk factors of Nigeria's child mortality were reported to be gender, maternal education, household wealth status, source of water, toilet facility, residence, mass media, frequency of antenatal and postnatal visits, marital status, place of delivery, multiple births, which decide healthcare used and the used of bed net, also the mortality risk is high among the maternal age group below 24 and above 44years. Adeyemi et. al (2019) proposed a hierarchical Bayesian modeling approach to simultaneously captured the over-dispersion caused by the effect of using different population sizes across the districts (regions), and the spatial auto-correlation inherent in the childhood mortality at districts (state) level in Nigeria, the cross sectional data of 31842 were extracted from 2013 Nigeria Demographic and health survey in which 2886 died before attaining age five, the Poisson regression models were employed with random effects to estimate the mortality risk and to investigate the association between the under-five child mortality and the regional risk factors. The result shows that the economically unbalanced household were positively significant to childhood mortality at 95% level of significance, while unhygienic sanitation and lack of access to improved water sources were positively associated with child mortality, but not statistically significant at 5% probability level. Adesina (2022) et.al their study used different regression estimators to analyze the demographic factors that affect live births and maternal mortality in Oyo State where the state of birth of children were thoughtfully looked into , such as Ceph, Twin, Stillbirth, Triplet, and Premature. The use of negative binomial regression, zero-inflated regression, Poisson, and quasi-Poisson regression were employed to determine the factors that contribute to live births and maternal mortality. The results showed that Ceph, triplets, and premature births were significantly associated with live births, while twins, stillbirths, and triplets were positively associated with maternal mortality and statistically significant at the 5% level. However, the log-likelihood functions of the four models were compared and found that the negative binomial regression model fitted the maternal mortality data better, while the quasi-Poisson regression model fitted the live birth data better. This suggests that the childbirth state of delivery is statistically significant factor that determines both live births and maternal mortality in Oyo State.

Fagbamigbe and Nnanatu (2021) examined the effect of a child's spatial location in Nigeria on their likelihood of dying before age five with other key covariates, the method of Bayesian geo-additive regression was employed to work with the 2018 Nigeria Demographic and Health Surveys data of under-five mortality rate which varied significantly across spatial locations in Nigeria with Kebbi, Jigawa, Kaduna, Kogi and Gombe states having the highest rates. It was found that women with primary school education and women of aged 38 years and above had a higher risk of a child dying before attaining age five and also, poverty, male children, low birth weight, and multiple births are additional factors associated with high death of children under five years age group.

Many studies have been done on MDGs relating to reducing infant mortality and improving maternal health. However, not many works have been done on the pre-natal stages as proxies to mortality which invariably affects population growth in Nigeria. Aside the effect of pre-natal stage as a risk factor of infant mortality in Oyo state, modeling population growth has been incorrectly specified due to notable gap in data documentation. Therefore, this work aimed at modeling the infant population based mortality in Oyo state. This is significant to address the problems of mortality and geometric increase in human population of the state. The data were collected from the Maternity Health Centres (MHCs) across all 33 LGAs of Oyo state, the simple random sampling were used to select number of MHCs in each LGA.

II. DESCRIPTION OF MATERNITY HEALTH CENTRES IN SENATORIAL DISTRICTS AND LOCAL GOVERNMENT AREAS IN OYO STATE

Maternity Health centres(MHCs) located in all 33 local government areas (LGAs) in Oyo State. This state is divided into three senatorial districts comprising all the 33 LGAs, Oyo North, Oyo Central and Oyo south senatorial districts. These centres were established during and after colonial administration patronized usually by people of low and middle socio-economic status. Among MHCs, Adeoyo Maternity Teaching Hospital established in 1928 serves as a referral health centre for many primary health centres and

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private clinics in all LGAs. The hospital has department of Obstetrics and Gynaecology with two consultants and many medical officers, senior medical and principal medical officers. The primary aim of establishing this hospital is to reduce infant and child mortality and improving maternal health included in SDGs. The retrospective case – control study of pre-natal, antenatal and postnatal conditions would be captured with specified scale of measurement.

Table 1: Distribution of Health Centres in Oyo State.

Type of health centre		Number of health centre in each type	Percentage
Primary	Public	679	55
	Private	79	7
Secondary	Public	27	2
	Private	448	36
Tertiary	Public	2	0.2
	Private	2	0.2
Total		**1237**	**100**

Source. https://library.procurementmonitor.org

Table 1 contains frequency distribution and number of types of health centres with percentages in three senatorial districts of Oyo state. As at the time of the survey, there are 1237 health centres in Oyo state. There are 758, 475 and 4 for primary, secondary and tertiary health centres respectively. These health centres are categorized as public and private for primary, secondary and tertiary types of health centre. Primary public (private) has 679(79) of health centres as against secondary public (private) health centres with 27(448) and tertiary public (private) with 2(2) health centres. The highest number of health centers were recorded in primary public followed by secondary private.

Table 2: Distribution of total number of health centres, selected local government areas with selected health centres in each senatorial district.

Districts	Number of health centres	Number of LGA in each District	Number of LGA selected	Number of health centre selected
Oyo north	357	13	4	141
Oyo central	468	11	4	156
Oyo south	410	9	3	112
Total	**1237**	**33**	**11**	**409**

Source. https://library.procurementmonitor.org

Table 2 contains number of health centres, LGA, selected LGA and selected health centres in each senatorial district. There are 357, 468 and 410 for Oyo North, Oyo central and Oyo south senatorial districts respectively. 4 LGAs with 141 health centres in Oyo North senatorial district, 4 LGAs with 156 health centres in Oyo central and 3 LGAs with 112 health centres in Oyo south were selected. Total number of LGA and health centres for the study are 11 and 409 respectively

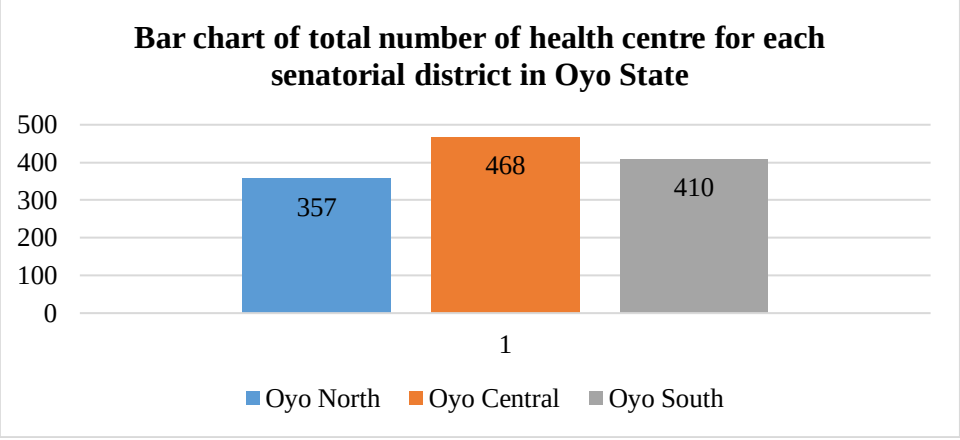

Fig. 1: Bar chart of total number of health centre for each senatorial district in Oyo State

Figure 1. shows the total number of health centres in each senatorial district. Oyo central has the highest number of health centre comprising primary, secondary and tertiary health centres.

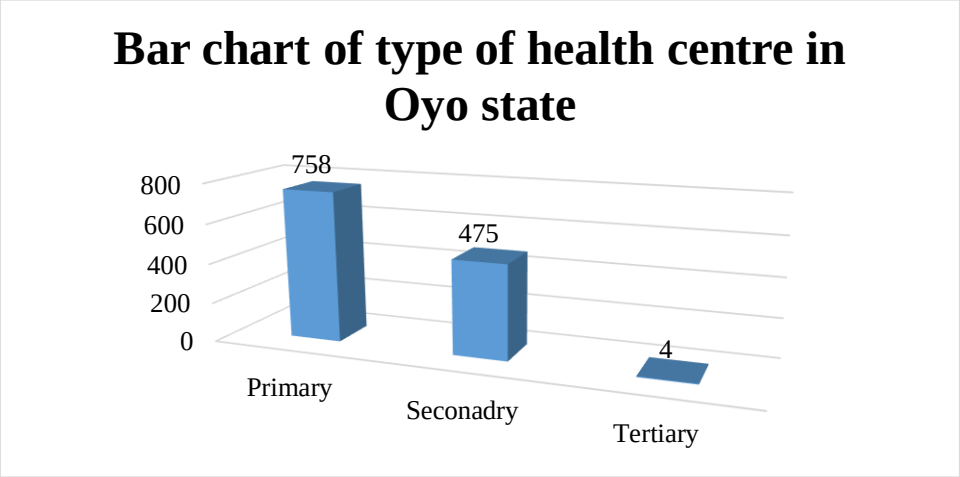

Fig. 2: Bar chart of type of health centre in Oyo state

Figure 2 shows the bar chart of total number of primary, secondary, tertiary health centres in Oyo state. Primary health centres has the highest number compared with other types of health centres in Oyo state.

Table 3: Distribution of antenatal and prenatal covariates on pregnant women in Oyo State

Anternatal	Attended	Not attended	Prenatal	Present	Absent
Government hospital	26	184	Doctor	47	163
Respondent's home	6	204	Nurse /midwife	67	163
Government health centre	29	181	Auxiliary midwife	5	205
Government health post	2	208	Extension health worker	8	202
Other public sector	0	210	Traditionalbirth attendant	0	210
Private hospital	21	189	Communityhealth worker	1	209
Private clinic	13	197	No one	1	209
NGO hospital	0	210			
NGO clinic	0	210			
NGOmedical sector	0	210			
Others	2	208			

Source: Nigerian Demographic Health Survey (2021)

Table 3 shows the distribution of antenatal care available to pregnant women in Oyo State. Total number of 29, 26, 21, 13 and 6 pregnant women registered at government health centre, government hospital, private hospital, private clinic and respondent's home respectively. This is obvious from table 2 that pregnant women do not register at registered health centres in the state. Also in Table 4 prenatal covariates are available to pregnant women. Total number of 67, 47, 8 and 5 for nurse/midwives, doctors, extension health workers an auxiliary midwives attended or present give medical care to pregnant women. These prenatal covariates are not evenly and adequately distributed as required by WHO.

III. MATERIALS AND METHOD

The datasets on infant mortality with prenatal covariates were randomly selected MHCs situated across 33 LGAs of three senatorial districts in Oyo State. Carefully constructed questionnaires on infant mortality, prenatal and antenatal covariates were administered to pregnant women at different locations of MHCs by Nigerian Demographic Health Survey (NDHS, 2021) from which real dataset used in this was sourced and extracted. The infant mortality measured as binary response variable, $y=1$ with p, probability that infant lived $y=0$ and $1-p$,probability that infant died. Infant mortality (IM) was estimated with the aids of logit function in Bayesian approach. Bayesian Binomial logit Model (BBLM) was developed for IM independently for Antenatal Covariate (AC) and Prenatal Covariate (PC), x_s mentioned in table 4.

IV. LIKELIHOOD FUNCTION OF INFANT MORTALITY MODEL

Infant mortality follows a binomial data over number of successes ($N_i,\ i=1,2,...,n$) given as: $y_i \sim Binomial(p_i, N_i)$. The likelihood function of model parameters is defined as

$$P(y/p)=\prod_{i=1}^{n}\binom{N_i}{y_i}p_i^{y_i}(1-p_i)^{N_i-y_i}$$

$$=\prod_{i=1}^{n}\binom{\sum_{i=1}^{n}N_i}{y_i}p_i^{\sum_{i=1}^{n}y_i}(1-p_i)^{\sum_{i=1}^{n}N_i-\sum_{i=1}^{n}y_i}$$

$$=\prod_{i=1}^{n}\binom{n}{y_i}p_i^{n\bar{y}}(1-p_i)^{n-n\bar{y}}$$

$$=\exp\left\{n\bar{y}\theta_0+\theta_{j-1}\sum_{i=1}^{n}x_{ij-1}y_i-\sum_{i-1}^{n}\log\left(1+e^{\theta_0+\theta_{j-1}x_{ij-1}}\right)\right\}$$

where

$$p_i=\frac{\exp(\theta x)}{1+\exp(\theta x)},\log\left(\frac{p_i}{1-p_i}\right)=\theta_0+\theta_1x_1+...+\theta_mx_m$$

,

In the absence of prior knowledge about the state of infant mortality, the use of non-informative priors are appropriate. In this study, multivariate normal priors with zero mean and large variance are used to express little or no information about the state of infant mortality.

$$p(\theta_j)\sim N(\mu_{\theta_j},\sigma^2_{\theta_j}),\ j=0,1,...,m$$

Then, posterior distribution of infant mortality

$$p(\beta_j/y)\propto p(y/\beta_j)p(\beta_j)$$

$$\propto\exp\left\{n\bar{y}\theta_0+\theta_{j-1}\sum_{i=1}^{n}x_{ij-1}y_i-\sum_{i=1}^{n}\log\left(1+e^{\theta_0+\theta_{j-1}x_{j-1}}\right)-\frac{1}{2}\left(\frac{\theta_0-\mu_{\theta_0}}{\sigma_{\theta_0}}\right)-\frac{1}{2}\left(\frac{\theta_{j-1}-\mu_{\theta_{j-1}}}{\sigma_{\theta_{j-1}}}\right)\right\}$$

Table 4: Bayesian Odds ratio of antenatal and pre natal covariates at MHCs in Oyo State.

Covariates	Mean	MSCE	95% Cred.Interval
BBLM	$logit(y)=\theta_iAC$		
Doctor	1.60181	0.147505	0.2891474 5.580301
Nurse /midwife	2.262288	0.305497	0.3512356 7.178421
Auxiliary midwife	1.820353	0.210486	0.155154 7.013962
Extension health worker	2.272213	0.215502	0.2456999 10.88337
Traditional birth attendant	1.582619	0.279341	0.1349229 7.185035
Community health worker	1.952255	0.17442	0.1786055 9.26417
No one	1.504947	0.110563	0.1510951 6.086368
BBLM	$logit(y)=\theta_iPC$		
Cashcraft	1.177785	0.009187	0.9818675 1.634846
government health center	7.20762	0.723547	2.062324 19.42266
government health post	0.9753123	0.098646	0.0832659 3.722961
public sector	2.379169	0.316717	0.3719564 8.287968
private hospital	3.436224	0.316343	0.4242038 13.56131
Private clinic	0.7399965	0.076563	0.1399325 2.463331
Respondent home	7.591619	1.19477	1.169909 28.75135
private medical sector	105.2913	15.8344	17.46564 358.8392
NGO hospital	1.791069	0.236686	0.2244738 6.321739
NGO clinic	2.350292	0.16908	0.3988239 7.197623
NGO medical sector	63.45842	6.35369	16.36091 167.0299
Other	25.47134	3.31344	4.905845 85.90144

Table 4 contains exponentiated estimates of prenatal covariates. The posterior odds ratios of all considered prenatal covariates of infant mortality show that that probability of a unit change in the number of above mentioned antenatal and pre natal covariates causes probability of a unit change in the infant mortality in Oyo state. This implies that the likelihood of increase in the number of health workers in Oyo State increases the likelihood of infant survival before and after birth. However, posterior Odds ratios of government health post and private clinic reduce the probability of infant survival at birth.

V. CONCLUSION

Infant mortality remains a major threat to population health. In the recent studies, effects of social- demographic covariates had been investigated by researchers. However, prenatal and antenatal effects of infant mortality have not been fully explored in Bayesian approach. The Derived BBLM for infant mortality was carried out to reduce mortality among infants when there is little information about those covariates. The BBLM derived for prenatal and antenatal is adequate and that health impacts of government health post and private clinic are not probabilistically related to infant survival.

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